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**THE NASA/DOD AEROSPACE KNOWLEDGE DIFFUSION
RESEARCH PROJECT: A RESEARCH AGENDA**

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National Aeronautics and Space Administration
Langley Research Center

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CONTRIBUTIONS TO INFORMATION SCIENCE**

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THE NASA/DOD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

A RESEARCH AGENDA

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**Conducted by Indiana University
and the NASA Langley Research Center**

**Sponsored by the National Aeronautics and Space Administration
and the Department of Defense with the cooperation of the
AIAA and AGARD Technical Information Panels**

THE NASA/DOD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

A Research Agenda

Introduction

Although the U.S. aerospace industry continues to be the leading positive contributor to the balance of trade among all merchandise industries, it is experiencing significant changes whose implications may not be well understood.¹ Increasing U.S. collaboration with foreign producers will result in a more international manufacturing environment, altering the current structure of the aerospace industry. International alliances will result in a more rapid diffusion of technology, increasing pressure on U.S. aerospace companies to push forward with new technological developments and to take steps designed to maximize the inclusion of recent technological developments into the research and development (R&D) process.

To remain a world leader in aerospace, the U.S. must take the steps necessary to improve and maintain the professional competency of U.S. aerospace engineers and scientists, enhance innovation and productivity, and maximize the inclusion of recent technological developments into the R&D process. How well these objectives are met, and at what cost, depends on a variety of factors, but largely on the ability of U.S. aerospace engineers and scientists to acquire and process the results of NASA/DOD funded R&D.

The ability of aerospace engineers and scientists to identify, acquire, and utilize scientific and technical information (STI) is of paramount importance to the efficiency of the R&D process. Testimony to the central role of STI in the R&D process is found in numerous studies (Fischer, 1980). These studies show, among other things, that aerospace engineers and scientists devote more time, on the average, to the communication of technical information than to any other scientific or technical activity (Pinelli, et al., 1989). A number of studies have found strong relationships between the communication of STI and technical performance at both the individual (Allen, 1970; Hall and Ritchie, 1975; and Rothwell and Robertson, 1973) and group levels (Carter and Williams, 1957; Rubenstein, et al., 1971; and Smith, 1970). Therefore, we concur with Fischer's (1980) conclusion that the "role of scientific and technical communication is thus central to the success of the innovation process, in general, and the management of R&D activities, in particular."

In terms of empirically derived data, very little is known about the diffusion of knowledge in the aerospace industry

¹"Aerospace" includes aeronautics, space science, space technology, and related fields.

both in terms of the channels used to communicate the ideas and the information-gathering habits and practices of the members of the social system (i.e., aerospace engineers and scientists). Most of the channel studies, such as the work by Gilmore, et al., (1967) and Archer (1964), have been concerned with the transfer of aerospace technology to non-aerospace industries.

Most of the studies involving aerospace engineers and scientists, such as the work by McCullough, et al., (1982) and Monge, et al., (1979), have been limited to the use of NASA STI products and services and have not been concerned with information-gathering habits and practices. Although researchers such as Davis (1975) and Spretnak (1982) have investigated the importance of technical communications to engineers, it is not possible to determine from the published results if the study participants included aerospace engineers and scientists. It is likely that an understanding of the process by which STI in the aerospace industry is communicated through certain channels over time among the members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of U.S. aerospace engineers and scientists.

Overview of the Federal Aerospace Knowledge Diffusion Process

A model (figure 1) that depicts the transfer of federally funded aerospace R&D is composed of two parts---the informal that relies on collegial contacts and the formal that relies on surrogates, information products, and information intermediaries to complete the "producer to user" transfer process. The producers are NASA and the DOD and their contractors and grantees. Producers depend upon surrogates and information intermediaries to complete the knowledge transfer process. When U.S. government technical reports are published, the initial or primary distribution is made to libraries and technical information centers. Copies are sent to surrogates for secondary and subsequent distribution. A limited number are set aside to be used by the author for the "scientist-to-scientist" exchange of information at the individual level.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Scientific and Technical Information Facility (NASA STIF), and the National Technical Information Service (NTIS). These surrogates have created a variety of technical report an-



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nouncement journals such as TRAC (Technical Report Announcement Circular) and STAR (Scientific and Technical Aerospace Reports) and computerized retrieval systems such as DROLS (Defense RDT&E Online System) and RECON (REmote CONsole) that permit online access to technical report databases.

Information intermediaries are, in large part, librarians and technical information specialists in academia, government, and industry. Those representing the producers serve as what McGowan and Loveless (1981) describe as "knowledge brokers" or "linking agents." Information in-

termediaries connected with users act, according to Allen (1977), as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process becomes (Goldhor and Lund, 1983). Active intermediaries take information from one place and move it to another, often face-to-face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed" (Eveland, 1987).

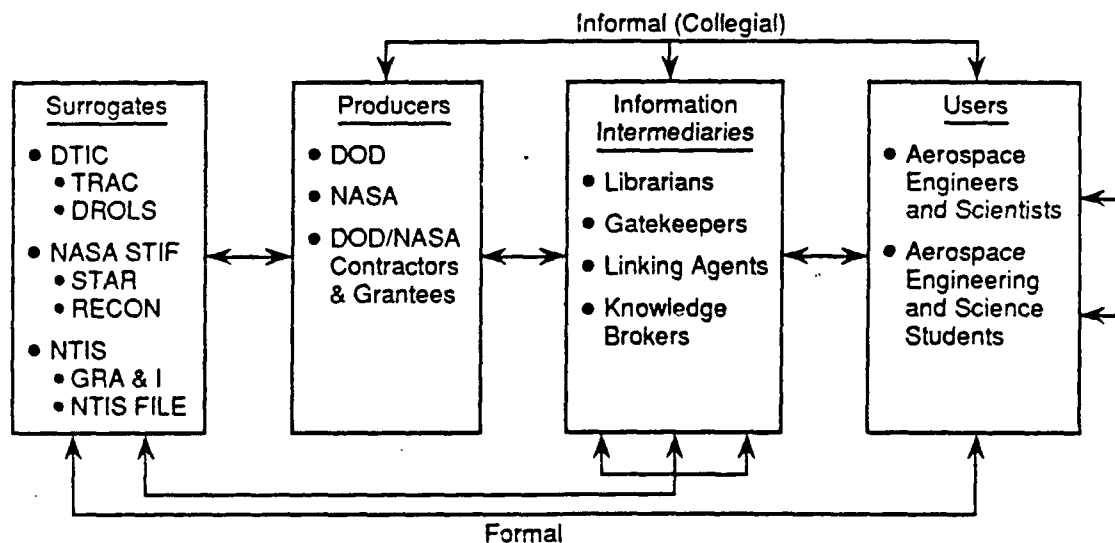


Figure 1. A Model Depicting the Transfer of Federally Funded Aerospace R&D.

The problem with the total Federal STI system is "that the present system for transferring the results of federally-funded STI is passive, fragmented, and unfocused." Effective knowledge transfer is hindered by the fact the Federal government "has no coherent or systematically designed approach to transferring the results of federally-funded R&D to the user" (Ballard, et al., 1986). In their study of issues and options in Federal STI, Bikson and her colleagues (1984) found that many of the interviewees believed "dissemination activities were afterthoughts, undertaken without serious commitment by Federal agencies whose primary concerns were with [knowledge] production and not with knowledge transfer"; therefore, "much of what has been learned about [STI] and knowledge transfer has not been incorporated into federally-supported information transfer activities."

The problem with the informal part of the system is that knowledge users can learn from collegial contacts only what those contacts happen to know. Ample evidence supports the claim that no one researcher can know about or keep up with all of the research in his/her area(s) of interest. Like other members of the scientific community,

aerospace engineers and scientists are faced with the problem of too much information to know about, to keep up with, and to screen—information that is becoming more interdisciplinary in nature and more international in scope.

Two problems exist with the formal part of the system. First, the formal part of the system employs one-way source-to-user transmission. The problem with this kind of transmission is that such formal one-way "supply side" transfer procedures do not seem to be responsive to the user context (Bikson, et al., 1984). Rather, these efforts appear to start with an information system into which the users' requirements are retrofit (Adam, 1975). The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer (Bikson, et al., 1984).

Second, the formal part relies heavily on information intermediaries to complete the knowledge transfer process. However, a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking (Beyer and Trice, 1982). In addition, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse

and inconclusive. The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context.

Project Overview

The NASA/DOD Aerospace Knowledge Diffusion Research Project is a cooperative effort that is sponsored by NASA, Office of Aeronautics, Exploration and Technology (OAET) and the DOD, Office of the Assistant Secretary of the Air Force, Deputy for Scientific and Technical Information. The research project is a joint effort of the Indiana University, Center for Survey Research and the NASA Langley Research Center. As scholarly inquiry, the project has both an immediate and a long term purpose. In the first instance, it provides a practical and pragmatic basis for understanding how the results of NASA/DOD research diffuse into the aerospace R&D process. Over the long term, it provides an empirical basis for understanding the aerospace knowledge diffusion process itself and its implications at the individual, organizational, national, and international levels.

Despite the vast amount of scientific and technical information (STI) available to potential users, several major barriers to effective knowledge diffusion exist. First, the very low level of support for knowledge transfer in comparison to knowledge production suggests that dissemination efforts are not viewed as an important component of the R&D process. Second, there are mounting reports from users about difficulties in getting appropriate information in forms useful for problem solving and decision making. Third, rapid advances in many areas of S&T knowledge can be fully exploited only if they are quickly translated into further research and application. Although the United States dominates basic R&D, foreign competitors may be better able to apply the results. Fourth, current mechanisms are often inadequate to help the user assess the quality of available information. Fifth, the characteristics of actual usage behavior are not sufficiently taken into account in making available useful and easily retrieved information.

These deficiencies must be remedied if the results of NASA/DOD funded R&D are to be successfully applied to innovation, problem solving, and productivity. Only by maximizing the R&D process can the United States maintain its international competitive edge in aerospace. The NASA/DOD Aerospace Knowledge Diffusion Research Project will provide descriptive and analytical data regarding the flow of STI at the individual, organizational, national, and international levels. It will examine both the channels used to communicate information and the social system of the aerospace knowledge diffusion process. The results of the project should provide useful information to R&D managers, information managers, and others concerned with improving access to and utilization of STI.

Project Assumptions

1. Rapid diffusion of technology and technological developments requires an understanding of the aerospace knowledge diffusion process.
2. Knowledge production, transfer, and utilization are equally important components of the aerospace knowledge diffusion process.
3. Understanding the channels; the information products involved in the production, transfer, and utilization of aerospace information; and the information-seeking habits, practices, and preferences of aerospace engineers and scientists is necessary to understand aerospace knowledge diffusion.
4. The knowledge derived from federally funded aerospace R&D is indispensable in maintaining the vitality and international competitiveness of the U.S. aerospace industry and essential to maintaining and improving the professional competency of U.S. aerospace engineers and scientists.
5. The U.S. government technical report plays an important, but as yet undefined, role in the transfer and utilization of knowledge derived from federally funded aerospace R&D.
6. Librarians, as information intermediaries, play an important, but as yet undefined, role in the transfer and utilization of knowledge derived from federally funded aerospace R&D.

Project Objectives

1. Understanding the aerospace knowledge diffusion process at the individual, organizational, and national levels, placing particular emphasis on the diffusion of federally funded aerospace STI.
2. Understanding the international aerospace knowledge diffusion process at the individual and organizational levels, placing particular emphasis on the systems used to diffuse the results of government funded aerospace STI.
3. Understanding the roles played by the NASA/DOD technical reports and aerospace librarians in the transfer and utilization of knowledge derived from federally funded aerospace R&D.
4. Achieving recognition and acceptance within NASA and the DOD and throughout the aerospace community that STI is a valuable strategic resource for innovation, problem solving and productivity.
5. Providing results that can be used to optimize the effectiveness and efficiency of the Federal STI aerospace transfer system and exchange mechanism.

Project Design

The initial thrust of the project is largely exploratory and descriptive; it focuses on the information channels and the members of the social system associated with the Federal aerospace knowledge diffusion process. As scholarly inquiry, the project has both an immediate and a long term purpose. In the first instance, it provides a pragmatic basis for understanding how the results of NASA/DOD research diffuse into the aerospace R&D process. Over the long term, the project will provide an empirical basis for understanding the aerospace knowledge diffusion process at the individual, organizational, national, and international levels. An outline of the descriptive portion of the project is contained in Table 1 as "A Five Year Program of Research on Aerospace Knowledge Diffusion." (See appendix.)

Phase 1 of the 4-phase project is concerned with the information-seeking habits and practices of U.S. aerospace engineers and scientists, with particular emphasis being placed on their use of federally funded aerospace STI products and services. (See Phase 1 of Table 1 on page 8.) A number of studies have indicated that researchers' information input and output activities are related or, at least, associated. Their communication behavior can be viewed as a system of information input and output activities and characterized as a series of complex interactions affected by a variety of factors. These factors influence the use and production of information and can be used to understand and explain the use and production of information sources and products (e.g., NASA/DOD technical reports).

The conceptual model shown in figure 2 assumes a consistent internal logic that governs the information-seeking and processing behavior of aerospace engineers and scientists despite any individual differences they may exhibit. This logic is the product of several interacting structural and sociometric factors, the purpose for which the information is needed, and the perceived utility of various information sources and products. The model is shown as a flow chart consisting of several functions and actions, including an evaluation function and a reinforcement function that provides feedback.

The results of the Phase 1 pilot study indicate that U.S. aerospace engineers and scientists spend approximately 65 percent of a 40-hour work week communicating STI. The types of information and the information products used and produced in performing professional duties are similar, with basic STI and in-house technical data most frequently reported. STI internal to the organization is preferred over external STI, which includes NASA/DOD technical reports, journal articles, and conference/meeting papers. Respondents identified informal channels and personalized sources as the primary method of STI seeking, followed by the use of formal information sources, when solving technical problems. Only after completing an informal search, followed by using formal information sources, do

they turn to librarians and technical information specialists for assistance.

Phase 2 focuses on aerospace knowledge transfer and use within the larger social system, placing particular emphasis on the flow of aerospace STI in government and industry and the role of the information intermediary (i.e., the aerospace librarian/technical information specialist) in knowledge transfer. (See Phase 2 of Table 1 on page 8.) In Phase 2, the process of innovation in the U.S. aerospace industry is conceptualized as an information processing system which must deal with work-related uncertainty through patterns of technical communications.

Information processing in aerospace R&D (figure 3) is viewed as an ongoing problem solving cycle involving each activity within the innovation process, the larger organization, and the external world. For purposes of this study, the innovation process is conceptualized as a process of related activities or units beginning with research at one end and service and maintenance on the other.²

These activities or units are highly differentiated, however. They operate on different time frames, with different goals, and with varying professional orientations (Rosenbloom and Wolek, 1970). These differences in norms and values also carry with them different internal coding schemes which suggest that each unit may possess specific and unique information requirements and information processing patterns. In addition, each unit is likely to have different sources of effective feedback, evaluation, and information support (Tushman and Nadler, 1980).

For any given task, each activity or unit within the innovation process "must [based on open system theory] effectively import technical and market information from the external information world" (Tushman and Nadler, 1980). New [external] and established [internal] information must be effectively processed within the work area; decisions, solutions, and approaches must be worked on and coordinated within each activity and within the organization; and outputs, such as decisions, processes, products, and information, must effectively be transferred to the external environment. The outputs of this process create conditions for another set of activities, thereby initiating another information processing cycle. Throughout the process, organizations must be sensitive to the differences between the activities or units that comprise the innovation process. Specialized feedback, evaluation, and support may be required to process new information from internal and external sources (Gerstberger, 1971).

It is, however, the nature of organizations engaged in innovation to isolate themselves from the outside world, to

²The proposition that innovation is a linear process, a view presented by Myers and Marquis (1969), is not universally accepted. Langrish, et al., (1972) have rejected "linear models" of the innovation process as unrealistic.

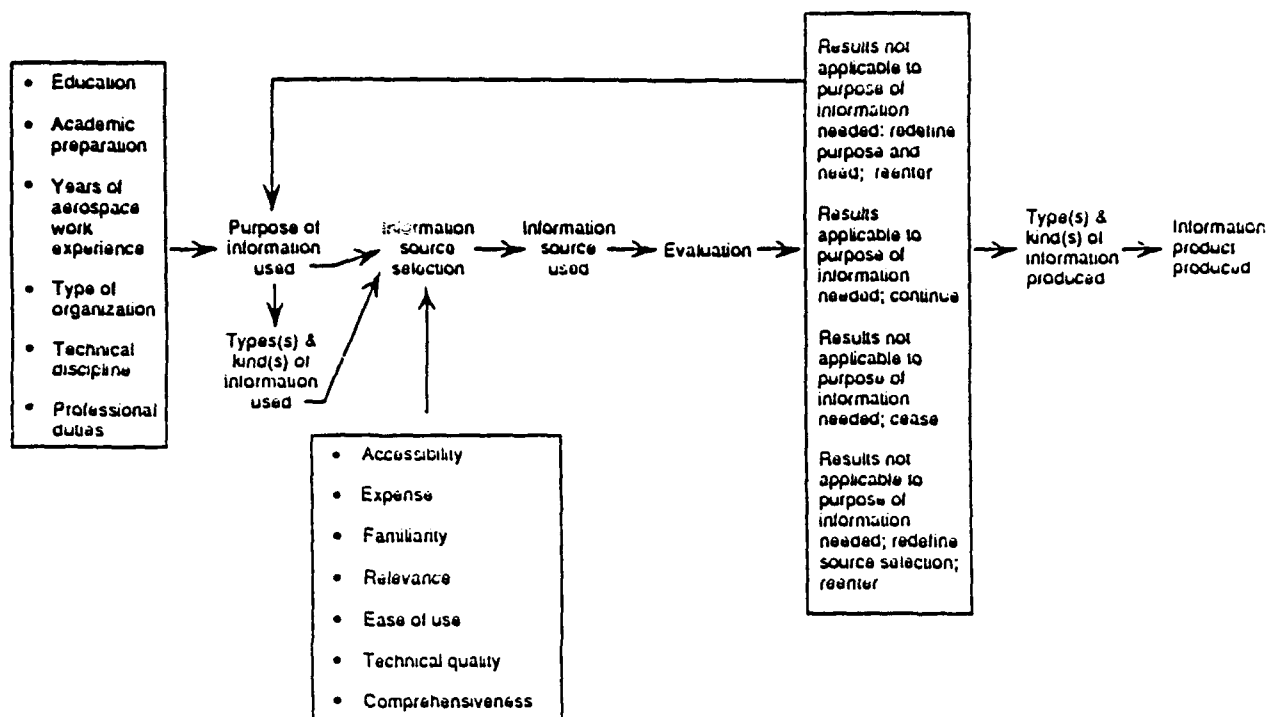


Figure 2. A Conceptual Model for the Use, Transfer, and Production of Scientific and Technical Information by U.S. Aerospace Engineers and Scientists.

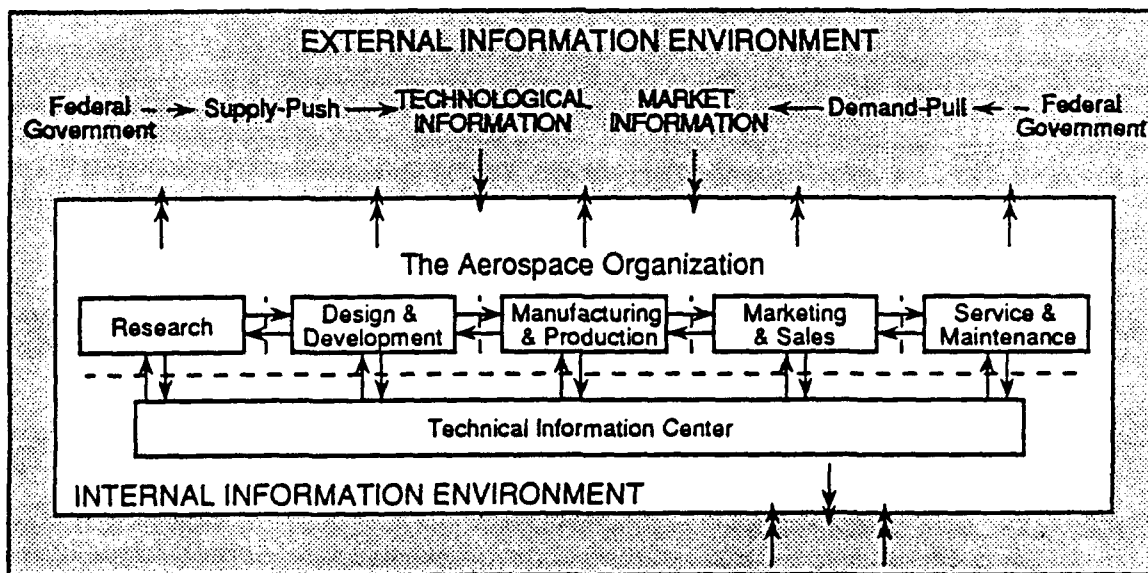


Figure 3. The Aerospace Innovation Process as an Information Processing System.

erect barriers to communication with their external environment, and to rely on information internal to the organization (Gerstenfeld and Berger, 1980). This behavior occurs because of the need for organizations to exercise control over those situations in which they interact with the "outside" and to reduce uncertainty, and because these organizations are frequently involved in activities of a proprietary nature (Fischer, 1980; Allen, 1970). Numerous studies have found a strong relationship between successful innovation, idea formulation, and information external to the organization (Dewhurst, et al., 1979; Allen, 1977; Project Sappho, 1972). The danger, then, for organizations engaged in innovation is to become isolated from their external environment and from information external to the organization (Fischer, 1980).

Phase 3 focuses on knowledge use and transfer at the individual and organizational levels in the academic sector of the aerospace community. (See Phase 3 of Table 1 on page 8.) Faced with shrinking enrollments, particularly at the graduate level, university aerospace programs must find ways to maintain the talent pool that will advance aerospace technological development and guarantee U.S. competitiveness. To prepare future aerospace engineers and scientists, academic programs must have access to "state of the art"

STI. Consequently, NASA and the DOD must ensure the effective and efficient delivery of Federally funded aerospace STI. An understanding of individual information-seeking behavior, the flow of aerospace STI, and the STI transfer system in academia should provide NASA/DOD with important insights for program development.

Phase 4 examines knowledge production, use, and transfer among non-U.S. individuals and aerospace organizations, specifically in Western Europe and Japan. (See Phase 4 of Table 1 on page 8.) As U.S. collaboration with foreign aerospace technology producers increases, a more international manufacturing environment will arise, fostering an increased flow of U.S. trade. At the same time, however, international industrial alliances will result in a more rapid diffusion of technology, prompting the U.S. aerospace industry to forge ahead with new technological developments. To cooperate in joint ventures as well as to compete successfully at the international level, U.S. aerospace industries will need to develop methods to collect, translate, analyze, and disseminate the best of foreign aerospace STI. Therefore, an understanding of the process by which non-U.S. aerospace engineers and scientists communicate at the individual and organizational levels becomes essential.

Project Status

The relative status of the four phases comprising the initial thrust of the project appears below. Status is stated in terms of definition, development, implementation, and analysis.

- o **Planning** Task is stated in terms of objectives to be accomplished and measurable outcomes; study group and sample frame identified; and feasibility and relative cost/difficulty established.
- o **Development** Task is planned and documented; questions formulated, reviewed, and pretested; questionnaires printed and transmittal letters prepared; sample selected and verified; and data collection and analysis established.
- o **Implementation** Task is undertaken; questionnaires are mailed, returned, and processed; and data are input, adjusted, and reduced.
- o **Analysis** Task is completed; data are analyzed, documented, and presented.

PROJECT	Planning	Development	Implementation	Analysis
Phase 1	●	●	◐	
Phase 2	●	●		
Phase 3	●	◐		
Phase 4	●			

○ TO BE DONE	◐ >50% COMPLETE	◑ >75% COMPLETE	● COMPLETE
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Project Reporting

In addition to periodic communication with the sponsoring organizations, project status will be reported on a quarterly basis. Status will be reported through the submission of written reports as well as oral presentations.

The principal vehicle for documenting the project results will be a series of NASA technical reports. In addition, papers will be presented at national and international conferences to keep the academic, government, and industrial aerospace information communities informed of project results and involved in the research process.

Project Publications

Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aeronautics: Results of an Exploratory Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534, Part 1, February 1989. 106 p. (Available from NTIS, Springfield, VA; 89N26772.)

Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aeronautics: Results of an Exploratory Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534, Part 2, February 1989. 84 p. (Available from NTIS, Springfield, VA; 89N26773.)

Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. **Technical Communications in Aeronautics: Results of an Exploratory Study--An Analysis of Managers' and Nonman-**

agers' Responses. Washington, DC: National Aeronautics and Space Administration. NASA TM-101625. August 1989. 58 p. (Available from NTIS, Springfield, VA; 90N11647.)

Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. **Technical Communications in Aeronautics: Results of an Exploratory Study--An Analysis of Profit Managers' and Nonprofit Managers' Responses.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101626. October 1989. 71 p. (Available from NTIS, Springfield, VA; 90N15848.)

Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. **The Value of Scientific and Technical Information (STI), Its Relationship to Research and Development (R&D), and Its Use by U.S. Aerospace Engineers and Scientists.** Paper presented at the European Forum "External Information: A Decision Tool" 19 January 1990, Strasbourg, France.

Blados, Walter R.; Thomas E. Pinelli; John M. Kennedy; and Rebecca O. Barclay. **External Information Sources and Aerospace R&D: The Use and Importance of Technical Reports by U.S. Aerospace Engineers and Scientists.** Paper prepared for the 68th AGARD National Delegates Board Meeting, 29 March 1990, Toulouse, France.

Kennedy, John M. and Thomas E. Pinelli. **The Impact of a Sponsor Letter on Mail Survey Response Rates.** Paper presented at the Annual Meeting of the American Association for Public Opinion Research, Lancaster, Pennsylvania, May 19, 1990.

Appendix

Table 1. A Five Year Program of Research on Aerospace Knowledge Diffusion

	Phase 1 1989-1990	Phase 2 1990-1992	Phase 3 1990-1991	Phase 4 1991-1993
Level	<ul style="list-style-type: none"> •National •Individuals •U.S. Aerospace Engineers and Scientists 	<ul style="list-style-type: none"> •National •Individuals and Organizations •Aerospace librarians in gov't and industry •U.S. gov't and aerospace industries 	<ul style="list-style-type: none"> •National •Individuals and Organizations •U.S. academic faculty, students, and engineering libraries 	<ul style="list-style-type: none"> •International •Individuals and Organizations
Focus	<ul style="list-style-type: none"> •Knowledge production and use 	<ul style="list-style-type: none"> •Knowledge transfer and use 	<ul style="list-style-type: none"> •Knowledge transfer and use 	<ul style="list-style-type: none"> •Knowledge production, transfer, and use
Emphasis	<ul style="list-style-type: none"> •Use, importance, and production of NASA/DOD STI (e.g., technical reports) •Impediments to access, transfer, and use of NASA/DOD STI •Use and importance of AGARD and foreign STI •Use and importance of information technology •Information sources used in problem solving 	<ul style="list-style-type: none"> •Use, importance, and production of NASA/DOD STI (e.g., technical reports) •Impediments to access, transfer, and use of NASA/DOD STI •Use and importance of AGARD and foreign STI •Use and importance of information technology •Effectiveness of system used to transfer federally funded STI •U.S. aerospace librarians in gov't and industry •Selected U.S. gov't facilities and aerospace companies 	<ul style="list-style-type: none"> •Use, importance, and production of NASA/DOD STI (e.g., technical reports) •Impediments to access, transfer, and use of NASA/DOD STI •Use and importance of AGARD and foreign STI •Use and importance of information technology •Effectiveness of system used to transfer federally funded STI •U.S. aerospace faculty, academic engineering libraries, and U.S. aerospace students (seniors) in USRA capstone design courses 	<ul style="list-style-type: none"> •Use and importance of NASA/DOD STI •Use of AGARD and non-U.S. STI •Impediments to access, transfer, and use of aerospace STI •Use of information technology •System used to transfer results of federally funded aerospace STI non-U.S. aerospace STI systems, policies, and practices
Subjects	<ul style="list-style-type: none"> •AIAA membership •SAE membership 	<ul style="list-style-type: none"> •Self-administered mail questionnaires •Personal interviews •Telephone follow-ups 	<ul style="list-style-type: none"> •Self-administered mail questionnaires •Personal interviews •Telephone follow-ups •Understanding of the internal flow of aerospace STI in gov't and industry 	<ul style="list-style-type: none"> •Pilot study •Self-administered mail questionnaires •Understanding of individual information-seeking behavior
Method	<ul style="list-style-type: none"> •Self-administered mail questionnaires •Telephone follow-ups •Understanding of individual information-seeking behaviors of U.S. aerospace engineers and scientists •Explain use/non-use of federal STI products and services by U.S. aerospace engineers and scientists 	<ul style="list-style-type: none"> •Self-administered mail questionnaires •Personal interviews •Telephone follow-ups •Understanding of the internal flow of aerospace STI in gov't and industry •Understanding of the system used to transfer results of federally funded aerospace STI 	<ul style="list-style-type: none"> •Self-administered mail questionnaires •Personal interviews •Telephone follow-ups •Understanding of the internal flow of aerospace STI in academia •Understanding of the system used to transfer results of federally funded aerospace STI 	<ul style="list-style-type: none"> •Pilot study •Self-administered mail questionnaires •Understanding of individual information-seeking behavior •Understanding of the system used to transfer results of federally funded aerospace STI •Understanding of non-U.S. aerospace STI systems, policies, and practices

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